About this Field Guide

The Energy Efficiency Guidelines

In early 2000 the State of Hawaii Department of Business, Economic Development & Tourism developed voluntary guidelines for energy-efficient design and construction of single family homes. Entitled *Guidelines for Energy Performance, Comfort, and Value in Hawaii Homes,* the *Guidelines* are a resource for architects, builders, developers, and owner-builders. The *Guidelines* identify significant opportunities to reduce energy use, improve comfort, lower utility bills, provide value, and improve the quality of life for Hawaii's home owners. (A copy of the *Energy Efficiency Guidelines* follows on page 3.) The overall approach in developing and implementing the *Energy Efficiency Guidelines* is to:

1. Reduce heat build-up and energy use in the home through passive cooling strategies that minimize or eliminate the need for air conditioning.

2. Reduce the need for electric lighting through the controlled use of daylight.

3. Reduce energy requirements even further by installing energy-efficient systems and equipment for water heating, lighting, household tasks, and air conditioning, when it is required.

The Field Guide

This *Field Guide* provides detailed illustrations and other information that show how to design and build an energy-efficient, comfortable, and economical home in Hawaii using the strategies recommended in the *Energy Efficiency Guidelines*.

Section I of the Field Guide provides basic information about climate, topography, and human comfort that lays the foundation for understanding the special opportunities and challenges when designing energy-efficient homes in Hawaii.

Sections II and III of the Field Guide present recommended techniques based on the *Energy Efficiency Guidelines*, along with illustrations and details that will help you implement the techniques for your home. Recommended techniques are identified as in the following example:

Recommended Technique: Use design elements to shade walls.

Section IV of the Field Guide discusses the cost of energy and the identifies several opportunities for significant cost savings, such as solar water heating, natural ventilation, and radiant barriers. *Section IV* also describes additional financial incentives and other resources available in Hawaii for building energy-efficient homes.

At the end of the *Field Guide* you will find these appendices:

Appendix A: Recommended Techniques—A summary listing of recommended techniques for (1) energy-efficient equipment and appliances, and (2) design.

Appendix B: Resources—Where to go for more information.

Appendix C: Bibliography—A list of the major sources for the information in this *Field Guide*.

Appendix D: Shading Formulas—Additional information related to developing a window shading design (discussed in *Section II*, Chapter 10).

Appendix E: Operation and Maintenance—A summary of operational "Do's and Don'ts" and maintenance tasks for common household appliances, which will help home owners *keep* their home operating in an energy-efficient manner.

Appendix F: Equivalencies for Energy Star® Homes in Hawaii— Energy Star® Homes developed these to aid implementation of Energy Star® for homes participating in the HECO, MECO, and HELCO solar domestic water heating programs.

Appendix G: Utility Co-Payments—A summary of co-payments available through utility programs that encourage the use of solar hot water heating systems and other energy-efficient measures.

Appendix H: Certification Programs and Other Resources—Information about certification programs that help identify environmentally preferable products.

Appendix I: Case Study—Model Demonstration Home—Description of the Model Demonstration Home (dedicated May 15, 2001, as the First Hawaii BuiltGreen™ Home), which incorporates affordable techniques to provide energy efficiency and comfort without air conditioning.

Note: This *Field Guide* is intended as a resource for builders and owner-builders wishing to improve the energy performance of homes in Hawaii. However, this document is not a substitute for nor does it eliminate professional design and engineering judgment or accepted engineering and construction practices. Each home and site may have characteristics that could render any one or more of the practices suggested in this *Field Guide* inappropriate or inapplicable. It is the responsibility of the home builder or owner-builder to select measures that are appropriate in each case. It is highly recommended that owner-builders consult with professionals when planning their home.

Guidelines for Energy Performance, Comfort, and Value in Hawaii Homes

I. Introduction. The *Energy Efficiency Guidelines* were prepared as a guide for home builders and owners to use in creating homes that are energy-efficient and comfortable with little or no air conditioning. The guidelines include suggestions for reducing the use of electric power in homes with a strong focus on how homes can be built for comfort without air conditioning. In this way, home owners can enjoy the indoor/outdoor life style and close contact with the natural environment that are so much a part of life in these Islands.

II. Design for Comfort and Value

A. Control Heat Gain: Use strategies to reduce solar heat gain through roofs, walls and windows.

1. Orient and arrange building to control heat gain.
2. Landscape and design outdoor surfaces to reduce air temperatures and glare; minimize paving area and use grassed and planted areas to provide lowered site temperatures, shade and evaporative cooling.
3. Shade roofs, walls and windows with:
    a. Architectural elements such as eaves, awnings and carports, and
    b. Window treatments such as blinds and shutters.
4. Use insulation and/or radiant heat barriers in roofs and walls exposed to the sun.
5. Use high performance windows (Low-e, spectrally selective, or tinted glazing) to keep solar heat out of interior spaces while admitting daylight.
6. Use light colored roofing and wall finishes.
7. Shade or insulate materials with high thermal mass, such as concrete floors, to avoid heat build up and uncomfortably hot surface temperatures.

B. Use Natural Ventilation: Provide ample fresh air ventilation for living spaces and areas where hot air and humidity accumulate, such as attics, high ceiling spaces, kitchens, bathrooms, and laundry areas.

1. Orient buildings to maximize the cooling potential of prevailing winds and minimize morning and afternoon heat gain.
2. Design floor plans and opening placement and type to provide effective cross ventilation with good air circulation throughout room areas and at body level.
3. Provide generous screened openings well protected from the rain.
4. Use architectural design elements such as vents and casement windows to improve interior air circulation.
5. Enhance natural ventilation with fans as needed:
    a. Use ceiling and whole house fans to provide comfort on warm, humid or still days.
    b. Use solar powered attic vent fans when appropriate and economically feasible.

III. Reduce Energy Bills.

A. Water Heating: Minimize the energy required for water heating.

1. Use solar water heating systems.
2. When solar water heating is not an option, use energy efficient alternatives such as heat pumps, high efficiency electric or gas water heaters.
3. Use high efficiency water tanks, insulate older tanks.
4. Insulate hot water supply lines.
5. Provide water heater thermostats adjustable to as low as 120˚ F.

B. Lighting: Minimize electric lighting energy demand and heat gain.

1. Use controlled, filtered and indirect daylighting to light interior spaces and reduce electric lighting loads. Increase the effectiveness of daylighting with generous wall openings, open floor plans and light colored interior finishes.
2. Use energy efficient electric lighting to reduce heat gain and energy demand.
3. Don't over light interior and exterior spaces. Use focused or task lighting in preference to whole room or large area lighting.
4. Provide controls such as timers, dimmers, sensors and separate fan/light controls to limit power use to the times and levels needed.
5. Use solar powered landscape lighting when economically feasible.

C. Appliances: Use energy efficient appliances.

1. Use energy efficient refrigerator, range, clothes and dish washers and dryers. Look for energy ratings and Energy Star® compliance labels.
2. Use microwave ovens to reduce reliance on less efficient cooking appliances.
3. Use laundry lines for clothes drying.

D. Air Conditioning: Use air conditioning only when it is required by special circumstances such as environmental noise, dust and pollution, very warm micro-climates, home offices where heat or humidity control is needed or to provide appropriate comfort levels for occupants with special needs.

1. If air conditioning is used, meet or exceed code recommendations for air conditioned buildings, including insulation requirements, shading of walls and windows and limits on glazing area.
   a. Seal the building envelope to prevent air leaks and loss of cooled air to the exterior and to control interior humidity levels.
   b. Shade windows or use high performance glazing.
2. Select and design energy efficient air conditioning system:
   a. Select minimum unit size and energy efficient system type to reduce operating and maintenance costs and facilitate repair.
   b. Design in zoning and controls to turn systems off when not needed; cool only spaces that need air conditioning, not the whole house.

c. Provide operable windows, screened doors and ceiling fans so that natural ventilation and fans can be used instead of the air conditioning system whenever possible.

3. Insulate and ventilate attic spaces housing air conditioning equipment and ducts.

4. Seal and insulate chilled water lines and cold air ducts in unconditioned spaces.

IV. Reduce environmental impact and life cycle energy costs of construction.

A. Refer to the guidelines in DBEDT's HABiT Guide to Resource Efficient Building in Hawaii and the DBEDT Clean Hawaii Center's "Construction & Demolition Waste Management Guide."

V. Take advantage of State income tax credits (See DBEDT's "Hawaii Energy Tax Credits" brochure) and utility program rebates (HECO [Oahu]: 947-6937; HELCO [Big Island]: 969-0127; Kauai Electric: 246-8280; MECO [Maui, toll-free]: 1-888-632-6786).

VI. Receive reduced mortgage costs through HECO's partnership with the U.S. Environmental Protection Agency's "Energy Star® Homes" mortgage program. Call the HECO, HELCO, and MECO numbers above.

VII. Honsador Lumber Corporation (682-2011) offers a predesigned home incorporating the three "Big Bang" techniques of these *Guidelines*: HECO-approved solar water heater, radiant barrier, and natural ventilation.

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Section I: Introduction

The first step in implementing the *Energy Efficiency Guidelines* approach is to reduce heat build-up through passive cooling strategies. It is therefore important to understand Hawaii's climate conditions and how to work with them in designing a home for improved comfort and quality of life. *Section I, Introduction*, focuses on this area and presents:

- Climactic opportunities and challenges when using an energy-efficient approach for the design of homes in Hawaii (Chapter 1)
- Human comfort and climatic conditions that affect design (Chapter 2)
- General climatic conditions in Hawaii that relate to human comfort (Chapter 3)
- Special site conditions that affect human comfort (Chapter 4)

Chapter 1: Building for Energy Performance, Comfort and Value in Hawaii

Typical climate conditions in Hawaii provide significant opportunities to build comfortable energy efficient homes without air conditioning. Mild temperatures and gentle trade winds make natural cooling viable while steady sunlight offers the ability to heat water with the sun.

Hawaii's climate does present challenges, however. Intense sunlight, occasional high humidity, and variable winds must be addressed to achieve optimum comfort levels. Specific locations may present conditions requiring additional thought.

Homes can be protected from the sun's heat through the use of passive cooling strategies that reduce heat gain and incorporate natural ventilation. Variable trade winds can be supplemented with ceiling fans and openings that admit air to circulate freely through the home.

Human beings are highly adaptable. If we live in close contact with our natural environment we develop greater tolerance for the brief periods in Hawaii when the weather may be too warm or too humid for comfort. A home designed to soften the impact of variations in temperature, humidity, and available breezes can provide comfort without air conditioning. This allows its occupants to enjoy Hawaii's mild climate and the indoor/outdoor life style that is so natural to the islands.

The advantages of a naturally cooled home compared to an inefficiently designed home with or without air conditioning is illustrated below. As outside temperatures climb throughout the morning and afternoon, an inefficient home without air conditioning heats up to temperatures that can be even hotter than outside. The home retains the heat and keeps interior temperatures high even while the outside air cools into the evening.

Air conditioned homes strive to create uniform temperature and humidity conditions. Occupants of such homes are isolated from the natural environment and suffer greater stress from temperature and humidity when they venture out of their homes.

In contrast, an efficiently designed home more closely parallels the outside temperatures and improves comfort conditions with fans during hot days when the air is still. An air conditioned home uses energy to maintain the home at uniform temperatures throughout the day. The difference between indoor and outdoor temperatures and the stress that home owners experience when they go from indoors to natural outdoor environment increases as the day warms.

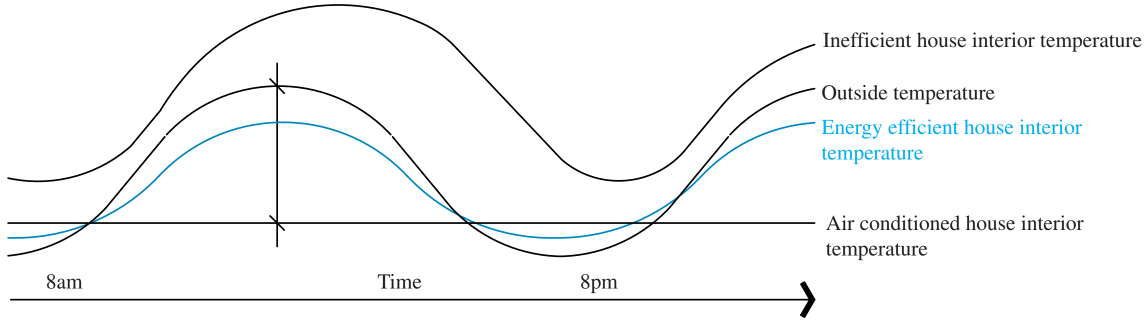


Fig. 1-1: A Comparison of Daily Temperature and Humidity Variations for an Air Conditioned Home, an Energy-Inefficient Home, and an Energy-Efficient Home.

Passive cooling strategies that eliminate the need for air conditioning will save the cost of the AC system (approximately $18,000 for central systems) and about $400 per year needed to run the system.

Solar hot water heaters can save a family of four approximately $626 a year based on 14.5¢ per kWh. Neighbor islanders can save even more, as the electricity rate is 18.5¢ per kWh on Maui, 21.8¢ on the Big Island, and 23.7¢ per kWh on Kauai, as of April 2001.

Energy efficient appliances perform better and cost less to operate than conventional models.

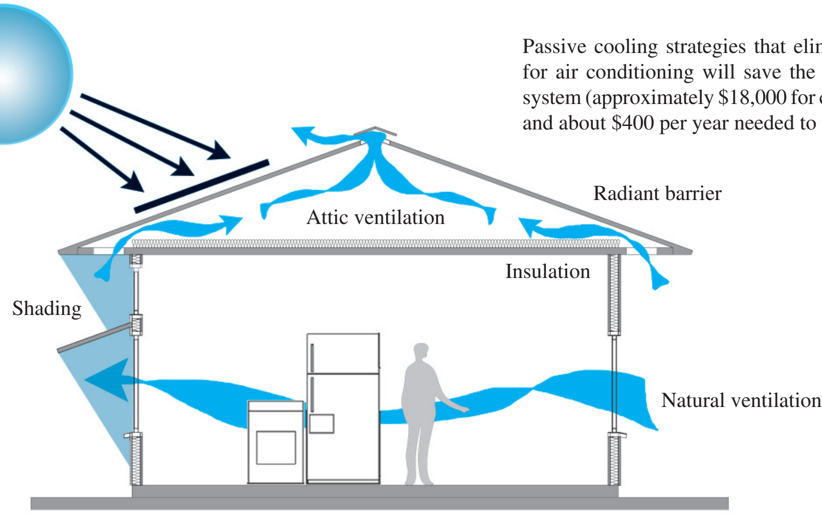


Fig. 1-2: A Well-Designed, Energy-Efficient Home.

In a well-designed energy efficient home without air conditioning, you can stay comfortably connected to the natural environment. You can also save money. Just eliminating air conditioning equipment can save about $400 a year in lower energy bills and, of course, the cost of the equipment and yearly maintenance. Incorporating the Guidelines comprehensively can provide substantial additional savings.

Special conditions can make air conditioning necessary. Examples include home offices where heat or humidity control is needed, occupants who have special needs, and neighborhoods where environmental noise, dust, pollution or very warm micro-climates are a problem. When air conditioning is used, the recommended approach is to employ passive cooling strategies first, then use only the amount of air conditioning actually required by limiting the areas and times of use.

Chapter 2: Climate and Comfort

Human comfort is affected by air temperature, humidity, air movement, solar and heat radiation, and temperature differences within a space and in building materials. Other factors, such as clothing, physical activity, physical condition, and non-climatic sources of heat and humidity (for example cooking, showers, and clothes washing) further affect comfort in the home.

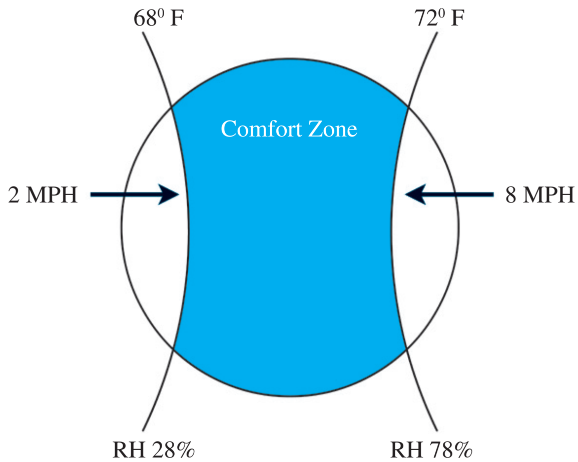


Fig. 2-1: Climate Conditions and the Human Comfort Zone.

Based on conventional research used to design air conditioning systems, most people are comfortable when the temperature is between the low 70s and low 80s degrees F and at relative humidity levels of 30% to 70%. These ranges apply when people are dressed in light clothing, are in the shade, and are relatively inactive.

Our perceptions of comfort and tolerance for changes in environmental conditions are affected by whether we have enjoyed the benefits of a naturally cooled environment or become dependent upon air conditioned spaces.

Recent research sponsored by the American Society of Heating, Refrigeration and Air Conditioning Engineers indicates that people in naturally ventilated buildings are comfortable over a wider range of temperature and humidity conditions than people accustomed to air conditioning. Perceived comfort in naturally ventilated buildings is affected by local climatic expectations and higher levels of personal control (occupants can choose appropriate clothing, open windows, or turn on fans).

Keeping Cool

Excess heat, whether from the environment or our own metabolism, must be removed to maintain a constant body temperature and thermal comfort. Mild air movement (less than 100 feet per minute) improves comfort levels when temperatures and humidity are high, aiding convective cooling and increasing the evaporation of perspiration. Air movement above 100 feet per minute can begin to be less effective and may be experienced as draft, and above 200 feet per minute (2 to 3 mph) can be annoying.

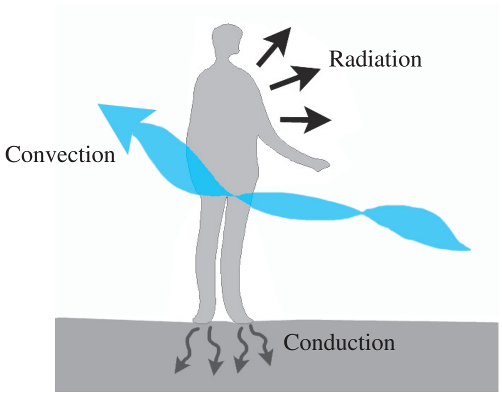


Fig. 2-2: Keeping Cool.

Our bodies eliminate excess heat through convection, radiation, and evaporation. *Convective cooling* occurs when air that is cooler than the body moves across the skin. *Radiant cooling* occurs when heat is radiated to the air from the skin. *Evaporation* of perspiration from the skin and in the respiratory tract also helps cool the body.

Chapter 3: Hawaii's Climate

Seasonal swings in temperature, precipitation, and wind conditions are moderate in Hawaii. Temperatures and humidity levels in Hawaii generally fall within or are only slightly outside of the ideal range for human comfort all year long. Fairly steady gentle trade winds help to offset these variations.

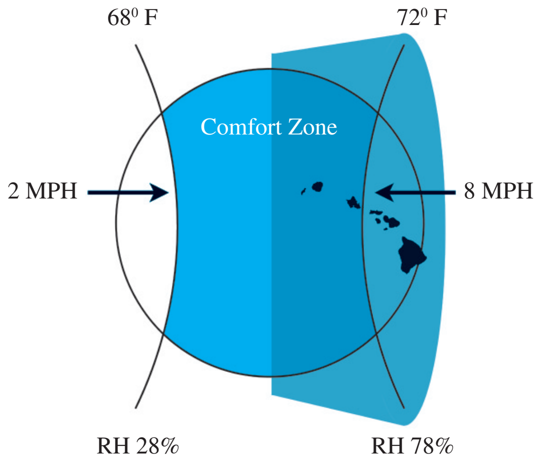
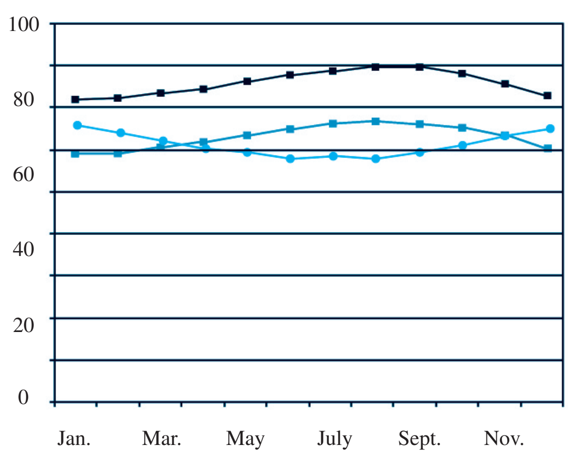


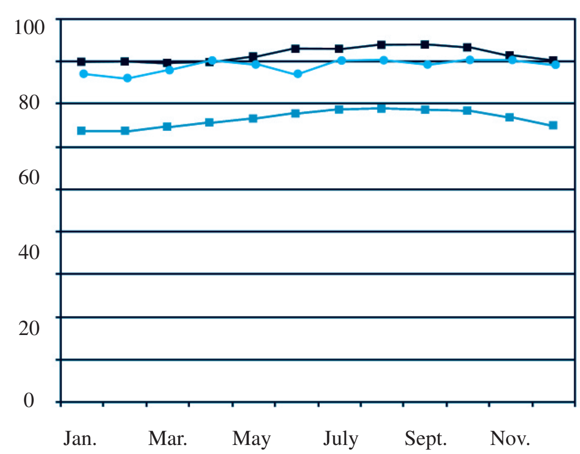
Fig. 3-1: Hawaii's Climate and the Human Comfort Zone.

Hawaii's climate provides near ideal temperature and humidity conditions throughout the year.

Sunlight and Temperature

The inhabited islands of the Hawaiian Island chain lie just within the tropics. Because of their low latitude, the islands experience relatively little annual variation in the length of the day, in sun angle and in solar insolation levels. (*Solar insolation* is energy received at ground level.) The surrounding ocean waters moderate temperatures and supply moisture to the air. In the course of the year, ocean temperatures range between 73^0 F and 80^0 F, with only a couple of degrees separating day and night time surface temperatures. Air temperatures closely parallel sea temperatures, with the yearly variation in average air temperature of 9^0 F or less.





Average high ⁰F Relative humidity % Average low ⁰F

Fig. 3-2: Average Monthly Temperature and Relative Humidity in Honolulu. January and February are the coolest months with average air temperatures of around 70^0 F in most locations. August and September are the warmest months with average air temperatures of around mid to high 80s.

Fig. 3-3: Average Monthly Temperature and Relative Humidity in Hilo.

The daily range in temperature in the islands (day to night) can easily exceed annual temperature variations. Lower lying areas, such as Honolulu, can experience daily temperature changes of 10˚ to 12˚ F. High mountain areas such as the upper slopes of Haleakala (Maui) and Mauna Loa (Big Island) can experience daily temperature changes of 20˚ or more.

The islands' typically cool evenings help make homes more comfortable during their primary hours of occupancy.

Rainfall and Humidity

Relative humidity is an important comfort factor closely related to rainfall. Hawaii has a general pattern of wet winters and drier summers, with winter storms providing Hawaii's heaviest rains during the October to April storm season.

Relative humidity ranges between average lows of 60% and average highs of 80% with typical yearly averages of 70%. The highest humidity levels occur during the rainier winter months, but the effect of humidity is felt the most in August, September, and October when temperatures are still high and winds are less dependable. Refer back to Figure 3-2.

Winds

Hawaii benefits from steady gentle trade winds typically moving at 15 to 20 mph from the northeast to the southwest. Trade winds are quite steady through much of the year, blowing approximately 50% of the time in winter and 90% of the time in summer. They tend to be stronger in the afternoon than at night.

Reading a wind chart

- Location of shaded area within circle represents wind direction.
- Concentric lines indicate amount of time during year wind comes from a particular direction.
- Shaded areas represent various wind velocities.

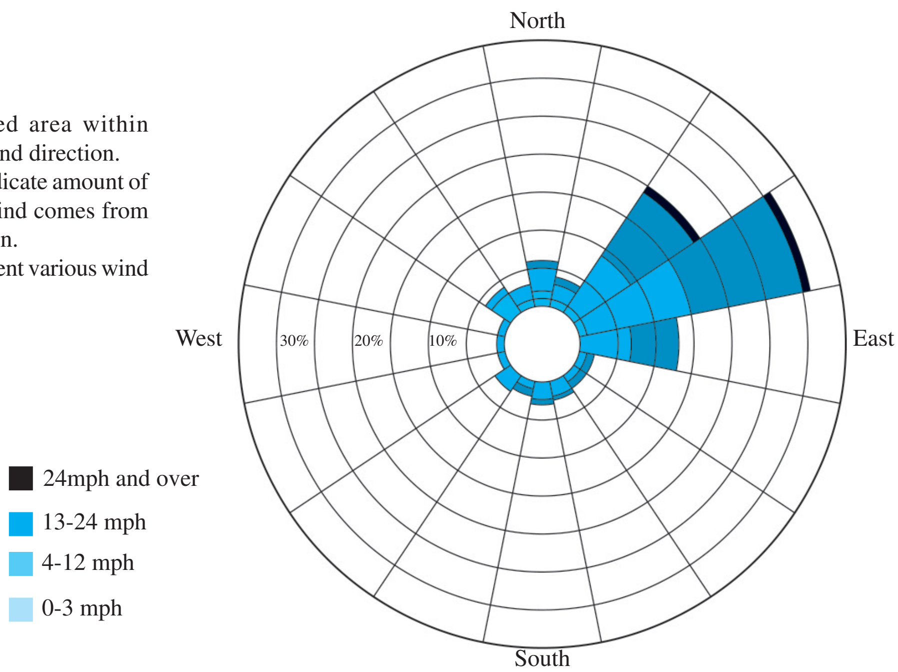


Fig. 3-4: Typical Trade Wind Patterns on Oahu (wind speed and direction).

Southerly or Kona winds occur with some regularity between October and April, and passing storms and cold fronts can bring southwest and north winds. Winter storms occurring between October and April can bring heavy rains and risk of damage from infrequent but potentially serious hurricanes.

Chapter 4: Special Site Conditions

Local site conditions play an important role in home design. To achieve optimum interior comfort at a given site, local variations or "micro-climate" conditions should be considered when identifying specific strategies for building and site design. These variations are largely the result of differences in elevation above sea level, topography, and orientation to the prevailing trade winds. See Figure 4-1, below. Additional data and references listed in the Appendices provide more information.

4
Special Site Conditions

Talk to people who are familiar with the area where you plan to build. In addition, observe the type and patterns of natural vegetation in the area. They can tell you a great deal about climate conditions.

Sunlight and Temperature

Solar radiation levels, average air temperature, and daily temperature range vary with elevation, exposure to the trades and cloud cover. Cloud cover is substantially more common on windward coasts and over lower mountain areas. Leeward coasts and high mountain areas receive the most sunlight.

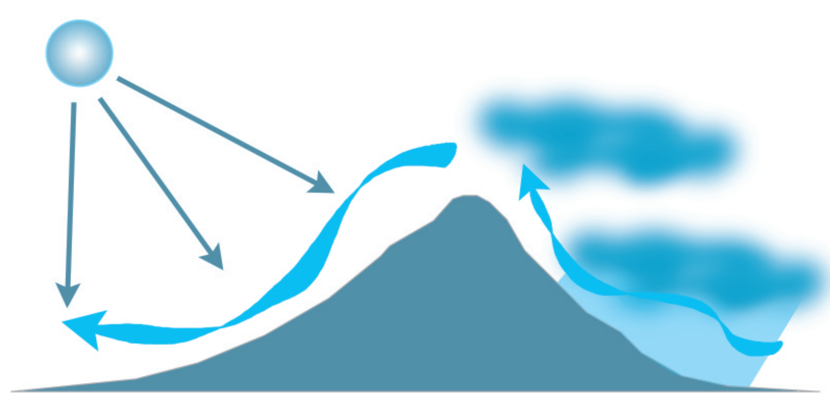
Fig. 4-1: Air Temperature Variation with Altitude.
Air temperatures decrease about 3^0 F per thousand feet of rise above sea level.

Rainfall and Humidity

Variations in rainfall are primarily due to differences in elevation, topography, and exposure to prevailing and seasonal winds. The open sea near Hawaii averages 25 to 30 inches of rain annually. Rainfall over the islands ranges from less than a third to fifteen times that amount. Humidity levels closely parallel rainfall patterns in the islands.

Fig. 4-2: Rainfall Patterns.

Mountains deflect the prevailing trade winds upward, cooling the air and trapping rain. Windward areas get substantially more clouds and rainfall than the nearby open sea and leeward areas. Leeward regions, where air that has lost its moisture over windward slopes descends, tend to be sunny and dry.



Adiabatic cooling (cooling as air rises and expands) combs rain from the moist ocean breezes that pass over the land. As a result, rainfall varies with altitude on windward slopes and closely parallels elevation on the lower islands.

Windward areas such as Hilo on the Big Island receive much of their rain during the cooler evening and early morning hours. Leeward areas such as the south and west shores of the island of Hawaii may get most of their rain in the afternoon and early evening hours when onshore breezes created by heating of the land pull moist sea air over the land and up mountain slopes.

Wind

Mountains and valleys affect airflow. Winds that normally rise on encountering mountain slopes may deflect around larger mountain masses. Wind flowing over ridges, around headlands, and through valleys often accelerates and becomes turbulent. High mountains on Maui and the Big Island significantly disrupt the smooth flow of the trade winds experienced on islands with lower mountain masses.

Protected leeward areas may be more affected by local and daily shifts in wind than by the trades. The Big Island with its high mountains and substantial land mass, sees a daily pattern on leeward coasts of air moving landward during the day and seaward at night as the land heats and cools relative to steady sea temperatures.

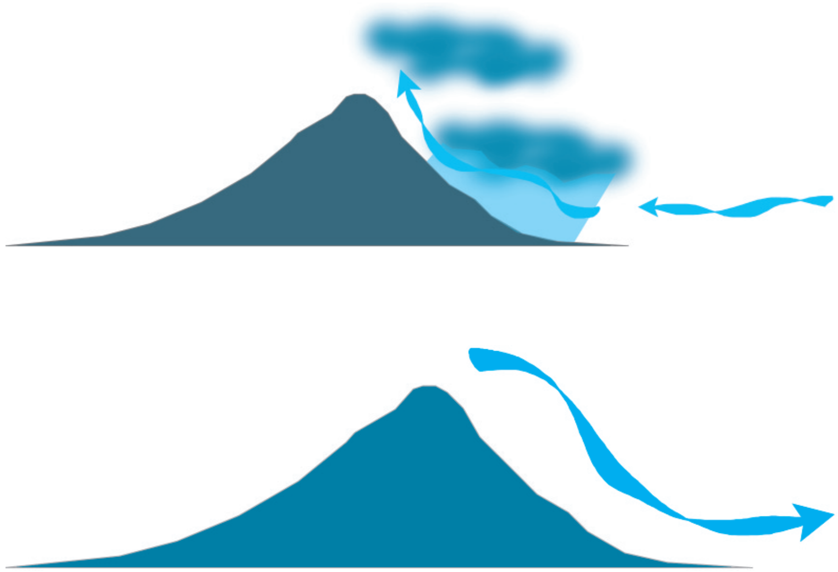


Fig. 4-3: Wind Patterns.

Warm onshore breezes during the afternoon and early evening hours can bring rain.

Offshore breezes at night and in the early morning hours can bring cooler temperatures.